POLSKI KOMITET NORMALIZACYJNY

POLSKA NORMA

ICS 77.040.01

PN-EN ISO 16859-2

Wprowadza
EN ISO 16859-2:2015, IDT
ISO 16859-2:2015, IDT

Zastępuje
–

Metale

Pomiar twardości sposobem Leeba

Część 2: Sprawdzanie i wzorcowanie twardościomierzy

Norma Europejska EN ISO 16859-2:2015 *Metallic materials – Leeb hardness test – Part 2: Verification and calibration of the testing devices (ISO 16859-2:2015)* ma status Polskiej Normy

nr ref. PN-EN ISO 16859-2:2015-12

ISBN 978-83-275-5334-8

Przedmowa krajowa

Niniejsza norma została zatwierdzona przez Prezesa PKN dnia 3 grudnia 2015 r.

Komitetem krajowym odpowiedzialnym za normę jest KT nr 123 ds. Badań Własności Metali.

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Norma Europejska EN ISO 16859-2:2015 została uznana przez PKN za Polską Normę PN-EN ISO 16859-2:2015-12.

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 16859-2

October 2015

ICS 77.040.10

English Version

Metallic materials - Leeb hardness test - Part 2: Verification and calibration of the testing devices (ISO 16859-2:2015)

Matériaux métalliques - Essai de dureté Leeb - Partie 2 : Vérification et étalonnage des appareils d'essai (ISO 16859-2:2015)

Metallische Werkstoffe - Härteprüfung nach Leeb - Teil 2: Überprüfung und Kalibrierung der Härteprüfgeräte (ISO 16859-2:2015)

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Ref. No. EN ISO 16859-2:2015 E

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European foreword

This document (EN ISO 16859-2:2015) has been prepared by Technical Committee ISO/TC 164 "Mechanical testing of metals" in collaboration with Technical Committee ECISS/TC 101 "Test methods for steel (other than chemical analysis)" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2016, and conflicting national standards shall be withdrawn at the latest by April 2016.

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INTERNATIONAL STANDARD

ISO 16859-2

First edition
2015-09-15

Metallic materials — Leeb hardness test —

Part 2: Verification and calibration of the testing devices

Matériaux métalliques — Essai de dureté Leeb —

Partie 2: Vérification et étalonnage des dispositifs d'essai

Reference number
ISO 16859-2:2015(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary Information

The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 3, *Hardness testing*.

ISO 16859 consists of the following parts, under the general title *Metallic materials — Leeb hardness test*:

— *Part 1: Test method*

— *Part 2: Verification and calibration of the testing devices*

— *Part 3: Calibration of reference test blocks*

Metallic materials — Leeb hardness test —

Part 2:
Verification and calibration of the testing devices

1 Scope

This part of ISO 16859 specifies methods for direct and indirect verification of test instruments used for determining Leeb hardness in accordance with ISO 16859-1, and also describes when these two types of verification are to be performed.

The direct verification involves checking that individual instrument performance parameters fall within specified limits, whereas the indirect verification utilizes hardness measurements of reference test blocks, calibrated in accordance with ISO 16859-3, to check the overall performance of the instrument for testing in the direction of gravity. The indirect method can be used on its own for the periodic performance checking in service.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16859-1, *Metallic materials — Leeb hardness test — Part 1: Test method*

ISO 16859-3, *Metallic materials — Leeb hardness test — Part 3: Calibration of reference test blocks*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

3 General conditions

Before a Leeb hardness testing instrument is verified, the instrument shall be checked to ensure that it is properly set up and operating in accordance with the manufacturer's instructions.

Especially it should be checked that

a) the impact body is correctly installed in the guide tube,

b) the support ring is mounted tightly to the bottom of the impact device,

c) cables are correctly connected, if applicable, and

d) the settings of the indicating unit are correct.

4 Direct verification

4.1 General

4.1.1 Direct verification should be carried out at a temperature of (23 ± 5) °C. If the verification is made outside this temperature range, this shall be reported in the verification report.

4.1.2 The instruments used for verification shall be traceable to national measurement standards.

4.1.3 Direct verification is comprised of the following:

a) verification of mass and geometry of impact body in accordance with 4.3;

b) verification of geometry of indenter ball, and of hardness of ball except for type E, in accordance with 4.4;

c) verification of geometry of support ring in accordance with 4.5;

d) verification of impact velocity in accordance with 4.6.

4.2 Calibration parameters

Calibration parameters for reference in direct calibrations of Leeb impact devices are specified in Table 1.

Table 1 — Dimensions of Leeb impact devices for reference in direct calibrations

			Parameters of types of impact devices						
			D	S	E	DL	D+15	C	G
v_A	m/s	Impact velocity[a]	2,05 ± 0,1	2,05 ± 0,1	2,05 ± 0,1	1,82 ± 0,1	1,7 ± 0,1	1,4 ± 0,1	3,0 ± 0,1
	mm	Maximum distance of ball indenter from test piece surface at velocity measurement	2,00	2,00	2,00	2,00	2,00	2,00	3,00
M	g	Mass of impact body (incl. ball indenter)	5,45 ± 0,1	5.40 ± 0,1	5,45 ± 0,1	7,25 ± 0,1	7,75 ± 0,1	3,1 ± 0,05	20,0 ± 0,3
R	mm	Spherical radius of indenter ball	1,5 ± 0,005	1,5 ± 0,005	1,5 ± 0,005	1,39 ± 0,005	1,5 ± 0,005	1,5 ± 0,005	2,5 ± 0,005
		Material of indenter	tungsten-carbide cobalt: balance; other carbides: < 2wt.-%; cobalt: 5–7 wt.-%; mass density 14,8 g/cm³ ± 0,2 g/cm³	ceramics Si_3N_4 > 90 wt.-%; mass density 3,1 g/cm³ ± 0,2 g/cm³	polycrystal-line diamond Syndite; mass density 3,5 g/cm³ ± 0,2 g/cm³	tungsten-carbide cobalt: balance; other carbides: < 2wt.-%; cobalt: 5–7 wt.-%; mass density 14,8 g/cm³ ± 0,2 g/cm³	tungsten-carbide cobalt: balance; other carbides: < 2wt.-%; cobalt: 5–7 wt.-%; mass density 14,8 g/cm³ ± 0,2 g/cm³	tungsten-carbide cobalt: balance; other carbides: < 2wt.-%; cobalt: 5–7 wt.-%; mass density 14,8 g/cm³ ± 0,2 g/cm³	tungsten-carbide cobalt: balance; other carbides: < 2wt.-%; cobalt: 5–7 wt.-%; mass density 14,8 g/cm³ ± 0,2 g/cm³
HV	HV2	Vickers hardness of Indenter	1600 ±100	1600 ±100	≥4500[b]	1600 ±100	1600 ±100	1600 ±100	1600 ±100
dx	mm	Minimum protrusion of spherical surface of indenter with respect to indenter holder	0,3	0,3	0,3	2,0	0,3	0,3	0,6
	mm	Dimensions of round bar of DL holder				diameter: 2,5 ± 0,1; length 55,15 ± 0,1			

[a] Impact vertically down, in direction of gravity.

[b] The indicated hardness of the indenter of impact body E is informational, but not required to be verified.

4.3 Verification of mass and geometry of impact body

4.3.1 The mass of the impact body shall be verified according to the requirements defined in Table 1.

4.3.2 The impact body shall consist of a ball indenter and a holder of the indenter. If the impact signal is read out via a coil using electromagnetic induction, the impact body shall contain a permanent magnet.

4.3.3 The spherical surface of the indenter shall protrude from the holder by a minimum of 0,3 mm for impact device types D, D+15, S, E, and C, and by a minimum of 0,6 mm for impact device type G. The indenter of impact device type, DL, is captured in a holder consisting of a round bar of diameter (2,5 ± 0,1) mm and length (55,15 ± 0,1) mm, and the indenter shall protrude from this holder by a minimum of 2 mm.

4.4 Verification of geometry and hardness of indenter ball

4.4.1 For the purpose of verifying the size and the hardness of the balls, a sample selected at random from a batch shall be tested. A certificate or proof of required hardness shall be made available. The balls verified for hardness shall be discarded.

4.4.2 The diameter of the ball indenter shall be determined by taking the mean value of not less than three single values of diameter measured at different positions on the ball. No single value shall differ from the nominal diameter by more than the tolerance given in Table 1.

4.4.3 The indenter of the impact body shall be made from tungsten-carbide cobalt, ceramics, or synthetic diamond, as specified in Table 1. The hardness shall conform with the specifications in Table 1, in accordance with ISO 6507-1. The ball can be tested directly on this spherical surface or by sectioning the ball and testing on the ball interior. The PCD balls do not require verification of hardness.

4.4.4 The spherical indenter surface shall be polished and free from surface defects when inspected under 100x total magnification.

4.5 Verification of geometry of support ring

The thickness of the support ring determines the distance of the ball indenter from the test piece surface at the velocity measurement. Verification of the thickness of the support ring is done through direct measurement. The thickness of the support ring shall be determined by taking the mean value of not less than three single values of thickness measured at different positions on the support ring. No single value shall differ from the nominal thickness by more than 0,1 mm.

4.6 Verification of impact velocity

4.6.1 Verification of the impact velocity should be done by direct velocity measurement in the direction of gravity. The impact velocity shall be measured at a maximum height of the indenter spherical surface above the test piece surface that is specified in Table 1.

4.6.2 If direct velocity measurement is not possible, an indirect verification of the velocity shall be conducted. For example, the impact body of the impact device can be replaced by a reference impact body that meets the parameter tolerances defined in ISO 16859-3:2015, Table A.1, and the impact device be connected to the reference indicating device. Following the impact in direction of gravity on a test piece, the displayed measurement signal can be compared to the reference signal value, as illustrated in Annex B. The signal waveform response before impact is instrument-specific and independent of the tested material.

4.7 Indirect verification of instrument

Following a successful direct verification, an indirect verification shall be performed in accordance with Clause 5.

5 Indirect verification

5.1 General

5.1.1 Indirect verification should be conducted at a temperature of (23 ± 5) °C using reference test blocks calibrated in accordance with ISO 16859-3. If indirect verification is done out of this temperature range, a note must be included in the verification report/calibration certificate.

5.1.2 Impact device, impact body, support ring, cables, and indicating device shall be inspected visually for exterior damage.

5.1.3 The resolution of the indicating unit shall be at least 1 HL.

5.1.4 The Leeb hardness testing instrument shall be tested for common hardness values using three reference test blocks from various hardness ranges according to Table 2.

Table 2 — Leeb hardness ranges

Type of impact device	Leeb hardness range for calibration HL[a]
D, D+15	< 500 500 to 700 > 700
DL, S	< 700 700 to 850 > 850
C, E	< 600 600 to 750 > 750
G	< 450 450 to 600 > 600

[a] HLD for impact devices D, HLD+15 for impact devices D+15, HLDL for impact devices DL, HLS for impact devices S, HLC for impact devices C, HLE for impact devices E, HLG for impact devices G.

5.2 Procedure

The reference test block shall be placed on a rigid support. Make 10 indentations on each reference test block uniformly distributed over the test surface in the direction of gravity. Testing shall be done in accordance with ISO 16859-1.

NOTE 1 For special applications, verification of the instrument can be limited to the hardness range corresponding to the hardness of the test pieces.

NOTE 2 Only the calibrated surface of the test blocks are to be used for testing.

NOTE 3 For testing in directions other than in direction of gravity, the measured hardness number will be different. For such cases, the applicable correction method can be provided by the manufacturer.

5.3 Variation coefficient (*V*)

$$V = \frac{s(H)}{\overline{H}} \cdot 100 \text{ in } \% \qquad (1)$$

where *s(H)* is the standard deviation from n = 10 Leeb hardness readings:

$$s(H) = \sqrt{\frac{\sum_{i=1}^{n}(H_i - \overline{H})^2}{n-1}} \qquad (2)$$

The arithmetic mean value $\overline{H}$ from n = 10 measured Leeb hardness readings is calculated as

$$\overline{H} = \frac{H_1 + H_2 + \ldots + H_n}{n} \quad (n = 10) \qquad (3)$$

where

$H_1, H_2, \ldots, H_n$ are measured Leeb hardness readings;

n is number of Leeb hardness readings.

The variation coefficient shall be considered as sufficient when meeting the requirements from Table 3.

5.4 Error of test instrument

The error of the test instrument

$$E = \overline{H} - H_{CRM} \qquad (4)$$

where

H_{CRM} is Leeb hardness of utilized reference test block.

The permissible error of the Leeb hardness test instrument is calculated from

$$E_{rel} = \frac{\overline{H} - H_{CRM}}{H_{CRM}} \cdot 100 \text{ in } \% \qquad (5)$$

The permissible error of the Leeb hardness tester, expressed in percentage of the given Leeb hardness of the reference test block, shall not exceed the limits given in Table 3.

Table 3 — Permissible variation coefficient and maximum permissible error of testing instrument on calibrated reference test blocks

<table>
<tr><th>Type of impact device</th><th>Leeb hardness of reference test block
HL[a]</th><th>Variation coefficient of testing instrument
V
%</th><th>Maximum permissible error of testing instrument
E_{rel}
%</th></tr>
<tr><td>D, D+15</td><td><500</td><td rowspan="4">2,5</td><td rowspan="4">±4,0</td></tr>
<tr><td>DL, S</td><td><700</td></tr>
<tr><td>C, E</td><td><600</td></tr>
<tr><td>G</td><td><450</td></tr>
<tr><td>D, D+15</td><td>500 to 700</td><td rowspan="4">2,0</td><td rowspan="4">±3,0</td></tr>
<tr><td>DL, S</td><td>700 to 850</td></tr>
<tr><td>C, E</td><td>600 to 750</td></tr>
<tr><td>G</td><td>450 to 600</td></tr>
<tr><td>D, D+15</td><td>>700</td><td rowspan="4">1,5</td><td rowspan="4">±2,0</td></tr>
<tr><td>DL, S</td><td>>850</td></tr>
<tr><td>C, E</td><td>>750</td></tr>
<tr><td>G</td><td>>600</td></tr>
<tr><td colspan="4">[a] HLD for impact devices D, HLD+15 for impact devices D+15, HLDL for impact devices DL, HLS for impact devices S, HLC for impact devices C, HLE for impact devices E, HLG for impact devices G.</td></tr>
</table>

5.5 Measurement uncertainty

Annex A contains an example estimation of measurement uncertainty for Leeb hardness results with a Leeb hardness tester.

6 Intervals between verifications

The schedules for the direct verifications of hardness testing instruments are given in Table 4. In addition, it is recommended that the impact body and support ring are directly verified or replaced after two years of use.

Indirect verification shall be done after a direct verification has been done, and it should be done once in 12 months, and shall not exceed 14 months.

Table 4 — Direct verification of Leeb hardness testing instruments

Requirements	Impact body	Impact device[b]	Support ring	Indenter tip
Before first use	×	×	×	×
Following repairs where impact energy, mechanical device, or testing cycle could be affected	×	×	×	×
When indirect verification has not been passed[a]	×	×	×	×
Last indirect verification > 14 months back	×	×	×	×

[a] These parameters need to be tested consecutively until the instrument passes indirect verification. They do not need verification in such cases where use of a reference impact body can prove that the indirect verification has been failed due to the original impact body.

[b] This parameter is verified using a reference impact body and reference indicating unit.

7 Verification report/calibration certificate

At minimum, the verification report/calibration certificate shall include the following information:

a) reference to this part of ISO 16859, i.e. ISO 16859-2;

b) type of verification/calibration (direct and/or indirect);

c) identification data for the hardness test instrument;

d) means of verification/calibration (reference test blocks, reference impact body, etc.);

e) Leeb hardness scale(s) verified/calibrated;

f) temperature during verification/calibration;

g) result obtained;

h) measurement uncertainty of verification/calibration results;

i) verification/calibration date and reference to the verification/calibration institution.

Annex A
(informative)

Measurement uncertainty of calibration results of Leeb hardness testing instrument

NOTE The structure of the metrological chain that is required to define and reproduce hardness scales is shown in ISO 16859-1:2015, Figure C.1.

A.1 Direct calibration of Leeb hardness testing instrument

A.1.1 Calibration of impact body and support ring

The impact body, which holds a spherical indenter made from tungsten-carbide cobalt, ceramics, or synthetic diamond on the impacting surface, and the support ring cannot be tested or calibrated on-site. A valid calibration certificate from an accredited calibration laboratory is required, attesting the geometrical deviations, the physical properties, and the chemical composition of the indenter (see 4.3).

A.1.2 Calibration of impact device using reference impact body and reference indicating unit

Indirect verification of the overall system is done with the reference impact body and the reference indicating device under laboratory conditions (see 4.4).

A.2 Indirect verification of Leeb hardness testing instrument

Indirect verification with reference test blocks is used to verify the overall performance of the Leeb hardness tester. The variation coefficient and the error of the Leeb hardness tester from the actual value of the reference test block are determined.

The measurement uncertainty of the indirect verification (see Reference [1]) of the Leeb hardness tester is given by Formula (A.1):

$$u_{\mathrm{HTM}} = \sqrt{u_{\mathrm{CRM}}^2 + u_{\mathrm{CRM-D}}^2 + u_{\mathrm{H}}^2 + u_{\mathrm{ms}}^2} \quad \text{(A.1)}$$

where

u_{CRM}	is calibration uncertainty of reference test block according to the calibration certificate for $k = 1$;
$u_{\mathrm{CRM-D}}$	is Leeb hardness change of reference test block since last calibration due to drift (negligible when using the reference test block in conformance to the standards);
u_{H}	is standard uncertainty of the Leeb hardness tester when measuring the CRM;
u_{ms}	is standard uncertainty due to limited resolution of the Leeb hardness tester.

EXAMPLE For values used, see Tables A.1 and A.2.

Leeb hardness of reference test block: H_{CRM} = (767 ± 5,5) HLD

Measurement uncertainty of reference test block: U_{CRM} = 5,5 HLD

Resolution of Leeb hardness tester: δ_{ms} = 1 HLD

Table A.1 — Results of indirect verification

No	**Leeb hardness reading** HLD
1	764_{min}
2	770
3	768
4	768
5	765
6	770
7	766
8	767
9	772_{max}
10	771
Mean value $\overline{H}$	768,1
Standard deviation s_H	2,6

$$E = \overline{H} - H_{CRM} \qquad (A.2)$$

$$E = 768{,}1 - 767 = 1{,}1 \text{ HLD}$$

$$u_H = \frac{t \cdot s_H}{\sqrt{n}} \qquad (A.3)$$

Using the Student's t-factor t = 1,06, n = 10 and s_H = 2,6 HLD:

u_H = 0,87 HLD

The uncertainty due to the limited resolution of the measurement system:

$$u_{ms} = \frac{\delta_{ms}}{2\sqrt{3}} \qquad (A.4)$$

$$u_{ms} = \frac{1}{2\sqrt{3}} = 0{,}29 \text{ HLD}$$

Table A.2 — Components of measurement uncertainty

Quantity X_i	**Estimated value** x_i HLD	**Standard uncertainty** $u(x_i)$ HLD	**Statistical distribution**	**Sensitivity coefficient** C_i	**Contribution to uncertainty** $_i(H)$ HLD
u_{CRM}	767	2,75	Normal	1,0	2,75
u_H	0	0,87	Normal	1,0	0,87
u_{ms}	0	0,29	Rectangular	1,0	0,29
u_{CRM-D}	0	0	Triangular	1,0	0
Combined uncertainty u_{HTM}					2,9
Expanded uncertainty U_{HTM} (k = 2)					5,8

Table A.3 — Maximum error of Leeb hardness testing instrument, incl. measurement uncertainty

Leeb hardness measured with the instrument $\overline{H}$ HLD	**Expanded measurement uncertainty** U_{HTM} HLD	**Error of testing instrument from calibration value of reference test block** E HLD	**Maximum error of testing instrument, incl. measurement uncertainty** ΔH_{HTMmax} HLD
768,1	5,8	1,1	6,9

Whereas

$$E = \overline{H} - H_{CRM}$$

$$\Delta H_{HTMmax} = U_{HTM} + |E| = 5{,}8 \text{ HLD} + 1{,}1 \text{ HLD} = 6{,}9 \text{ HLD}$$

The result of this example means that the test instrument meets the maximum permissible error of ±2,0 % from Table A.3, incl. measurement uncertainty of the testing instrument.

Annex B
(informative)

Direct verification of single coil instrument

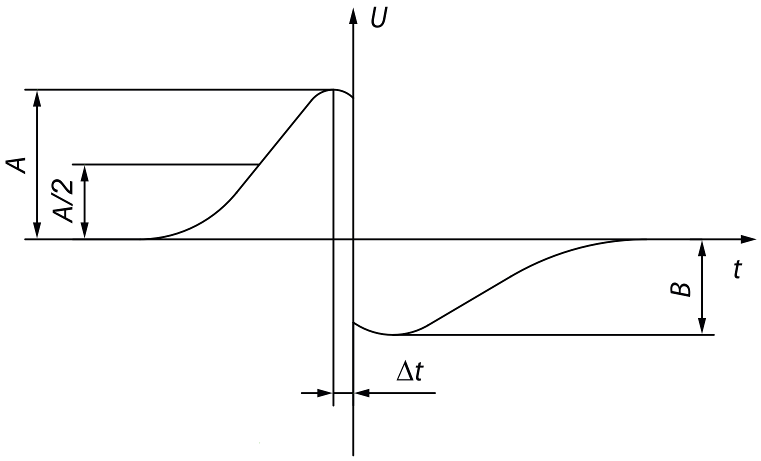
Figure B.1 shows the typical signal (induction voltage, *U*, vs. time, *t*) of a single coil test instrument. The critical part of the signal curve comes before impact, since it is instrument-specific and independent of the test material. An indirect verification of the velocity before impact can be conducted.

Δt is the time between the event of the peak voltage and the voltage zero crossing. Δt is inverse proportional to the impact velocity v_A. The Δt values with permissible maximum deviations are tabulated in Table B.1.

Table B.1 — Δ*t* of Leeb impact devices for reference in direct calibrations

Symbol	Unit	Designation	Parameters of types of impact devices						
			D	S	E	DL	D+15	C	G
Δt	ms	Time between peak voltage and voltage zero crossing[a]	0,55 ± 0,15	0,55 ± 0,15	0,55 ± 0,15	0,65 ± 0,15	0,55 ± 0,15	0,75 ± 0,15	0,55 ± 0,15

[a] Impact vertically down, in direction of gravity.



Key

A voltage amplitude in mV, proportional to impact velocity

B voltage amplitude in mV, proportional to rebound velocity

U voltage in mV

Δt time in ms between peak voltage and voltage zero crossing

Figure B.1 — Schematic drawing of principle signal of a Leeb hardness testing instrument (single coil)

Bibliography

[1] ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ICS 77.040.10

Price based on 12 pages